EFFECT OF HIGH INTENSITY INTERVAL TRAINING AND INTERVAL TRAINING ON SELECTED PHYSICAL AND PHYSIOLOGICAL VARIABLES OF BADMINTON PLAYERS

SHORT SYNOPSIS

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CERTIFICATE

I hereby declare that the short synopsis "**Effect of High Intensity Interval Training and Interval Training on Selected Physical and Physiological Variables of Badminton Players"** being submitted in partial fulfilment of the requirement for the degree of Doctor of Philosophy in physical education under the faculty of physical education of Lakshmibai national institute of physical education, Guwahati, during the academic tear 2022-23.

It is a Bonafide record of the original work carried out under the supervision of Dr. Shailesh Kumar Singh has not been submitted to any other university or institute for a degree or diploma. Further, it is certified that the short synopsis is plagiarism-free, and the proof has been submitted.

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ABSTRACT

This experimental study investigates the comparative effects of High-Intensity Interval Training (HIIT) and Interval Training (IT) on selected physical and physiological variables among male badminton players. The purpose is to determine whether HIIT leads to greater improvements in performance outcomes than traditional IT methods. A total of 45 male badminton players aged 19 to 25 years from Roing, Lower Dibang Valley district in Arunachal Pradesh were randomly assigned into three groups: Group I (HIIT), Group II (IT), and Group III (Control). The eight key variables assessed include aerobic capacity, anaerobic capacity, vital capacity, glucose level, agility, jumping ability, flexibility, and balance. Over a structured training period, the HIIT and IT groups underwent their respective interventions, while the control group followed no specialized training. The study aims to assess whether significant improvements in physical and physiological performance occur due to HIIT, and whether it proves more effective than IT in enhancing the athletic capabilities of badminton players. Although factors such as nutrition, medication, emotional state, and personal routines are considered limitations, the study remains within defined parameters of controlled training and homogenous participant selection. The findings of this study are expected to contribute to the optimization of sport-specific conditioning programs in badminton.

Keywords: High-Intensity Interval Training, Interval Training, Badminton, Aerobic Capacity, Anaerobic Capacity, Agility, Jumping Ability, Flexibility, Balance, Vital Capacity, Glucose Level

1 INTRODUCTION

Badminton is a fast-paced, intermittent sport that requires a combination of anaerobic power, aerobic endurance, agility, and mental alertness. Given the sport's demand for explosive bursts of movement interspersed with short periods of recovery, interval training and HIIT are especially effective in conditioning badminton players. These training modalities enhance both the aerobic and anaerobic energy systems, improve metabolic function, and simulate the physical demands of match play (Stølen et al., 2005). Stølen et al. emphasized that intermittent sports like badminton require specific training that reflects the game's start-stop patterns, and they demonstrated that high-intensity interval formats are more effective than continuous exercise in improving match-relevant performance markers such as agility, sprinting speed, and recovery efficiency.

Interval training refers to a structured training method where periods of intense exercise are alternated with short active resting periods. This strategy aligns well with badminton's nature, where rallies last a few seconds to over a minute, followed by short breaks. In badminton, interval training can include: on-court footwork drills in intervals (e.g., 30 seconds of fast footwork, 15 seconds rest), court sprints or shuttle runs, and skill-based interval routines like multi-shuttle drills or net kill exercises. These formats mimic the metabolic and biomechanical loads of a competitive match, allowing players to develop sport-specific endurance while refining their technique. Physiological benefits of interval training in badminton include increased VO_2 max and aerobic capacity, enhanced lactate threshold, and improved phosphocreatine (PCr) recovery. Elevated neuromuscular coordination and power output are also key benefits associated with interval work, particularly when applied to movement-specific training (Laursen & Jenkins, 2002). In their foundational work, Laursen and Jenkins (2002) highlighted that HIIT and interval training optimize both central and peripheral cardiovascular adaptations, making them superior for endurance development in high-tempo sports in comparison to the moderate-intensity continuous training.

HIIT is a form of interval training characterized by short bursts of high-intensity exercise (typically ≥85% of maximum effort) followed by a brief rest or active recovery. For badminton players, HIIT provides a time-efficient method to build cardiovascular endurance, muscular endurance, and anaerobic capacity (Gibala et al., 2006). Gibala et al. (2006) revealed that HIIT protocols, even when performed with low training volume, lead to mitochondrial biogenesis and oxidative enzyme activation comparable to that of traditional endurance training, suggesting HIIT's profound efficiency in improving both endurance and metabolic capacity. HIIT Formats for Badminton include the Tabata Protocol (20 seconds of maximal effort such as jump smashes or rapid footwork followed by 10 seconds of rest, repeated for 4 minutes), 30-20-10 Drills (alternating between

30 seconds moderate, 20 seconds high, and 10 seconds all-out intensity), and Multi-feed Shuttle Drills, which involve quick successions of shuttle feeds with minimal rest to develop reactive speed and recovery under fatigue. Research shows that HIIT significantly improves both aerobic and anaerobic performance in intermittent sports like badminton. It also enhances metabolic flexibility and cardiovascular efficiency (Buchheit & Laursen, 2013). Buchheit and Laursen's (2013) comprehensive review concluded that sport-specific adaptations to HIIT include improved oxygen uptake kinetics, reduced heart rate at submaximal workloads, and enhanced recovery between high-effort efforts—all of which are critical for badminton players dealing with repeated bursts of explosive activity.

Recent studies show strong support for HIIT's efficacy in racket sports. For instance, Kovacs (2007) found that interval training improved both aerobic and anaerobic power in tennis players, a sport similar to badminton in terms of movement variability, short work intervals, and rapid recovery demands. His research highlighted improvements in stroke efficiency, match endurance, and speed agility in athletes undergoing HIIT. Gibala et al. (2012) further reinforced these outcomes by demonstrating that just six sessions of low-volume HIIT produced significant improvements in endurance performance, muscle oxidative capacity, and insulin sensitivity, even in previously untrained participants. These findings illustrate the metabolic benefits of HIIT that can translate directly to competitive badminton settings. In badminton-specific contexts, Phomsoupha and Laffaye (2015) emphasized that repeated sprint ability and explosive efforts were significantly enhanced through HIIT-style drills. Their biomechanical analysis confirmed that players who trained with intermittent sprint and footwork protocols developed improved movement economy, stroke consistency, and responsiveness under fatigue.

Interval training and HIIT offer powerful, sport-specific tools for improving badminton performance. These methods improve energy system efficiency, enhance recovery, boost speed and agility, and build psychological resilience — all vital attributes for competitive players. When strategically implemented and individualized to an athlete's level, these training modalities can significantly elevate performance while minimizing the risk of injury.

2 LITERATURE REVIEW

High-Intensity Interval Training (HIIT) and interval training have emerged as essential components in the conditioning of athletes engaged in intermittent, high-intensity sports such as badminton. This training is effective for enhancing both aerobic and anaerobic systems, muscular endurance, agility, and recovery capacity. This literature review explores relevant research on the application of HIIT and interval training, with a specific focus on their physiological, psychological, and performance-based outcomes in the context of badminton.

Gibala and McGee (2008) highlighted the potent cellular and metabolic adaptations induced by high-intensity interval training (HIIT), traditionally associated with prolonged endurance workouts. Their research demonstrated that HIIT stimulates mitochondrial biogenesis, enhances oxidative enzyme activity, and promotes greater glycogen storage capacity within skeletal muscle. These physiological changes increase the muscle's ability to produce energy efficiently, delay fatigue, and sustain repeated efforts—qualities that are especially beneficial for badminton players. Given the sport's unique combination of anaerobic bursts (short, explosive movements during rallies) and aerobic recovery (brief rest intervals between points), such adaptations support rapid recovery, sustained intensity, and overall improved match endurance. This research supports the inclusion of HIIT as a time-efficient alternative to traditional long-duration training, particularly in badminton, where court time is often prioritized for skill development and tactical refinement.

Laursen and Jenkins (2002) provided foundational evidence supporting the effectiveness of high-intensity interval training (HIIT) in enhancing VO_2 max and lactate threshold, two critical determinants of aerobic endurance and fatigue resistance. Their review concluded that HIIT elicits more pronounced central cardiovascular adaptations (such as increased cardiac output and stroke volume) and peripheral adaptations (including improved capillary density and mitochondrial enzyme activity) compared to traditional moderate-intensity continuous training. These physiological improvements allow athletes to sustain higher intensities for longer durations and recover more efficiently between efforts—key traits in badminton, where matches demand rapid, repeated accelerations and short recovery periods. The ability to delay lactate accumulation and maintain a higher oxygen uptake threshold directly supports a badminton player's capacity to endure intense rallies while maintaining precision and coordination.

Buchheit and Laursen (2013) emphasized that repeated sprint training, a form of high-intensity interval training (HIIT), significantly enhances an athlete's repeated sprint ability (RSA) and recovery kinetics. These adaptations are critical in high-tempo sports such as badminton, where players engage in frequent short-duration sprints followed by limited recovery time. Enhanced RSA ensures that athletes can sustain high-intensity movements consistently throughout the match, while improved recovery kinetics allow for quicker restoration of performance between points and rallies.

Bangsbo, Iaia, and Krustrup (2008) found that intermittent training, characterized by alternating high- and low-intensity efforts, improves time-to-exhaustion, aerobic power, and match performance in both field and court-based sports. Their findings support the use of interval-based conditioning in badminton to build the endurance necessary for long matches while maintaining explosive performance throughout. Together, these studies affirm the role of structured high-intensity training in enhancing both physiological capacity and sport-specific performance.

Phomsoupha and Laffaye (2015) conducted an in-depth review of elite badminton performance characteristics, emphasizing the sport's biomechanical and physiological demands. Their findings underscore that badminton is inherently intermittent and high-intensity, consisting of short-duration rallies and brief rest periods, which places unique stress on both aerobic and anaerobic systems. Due to this match structure, they recommend high-intensity interval training (HIIT) as an ideal conditioning method that mirrors the energy system demands and movement patterns of actual gameplay. HIIT protocols that replicate game-specific actions—such as multidirectional footwork, shuttle-based intervals, and simulated rally drills—can significantly improve performance markers like agility, speed, and recovery capacity. Moreover, they assert that traditional continuous aerobic training lacks specificity and does not effectively prepare athletes for the fast-paced, stop-and-go nature of badminton. HIIT, when designed with sport-specific drills, promotes better transfer of fitness gains to competitive play and enhances technical-tactical performance under fatigue. Their review supports the application of HIIT not just for general fitness but as a strategic tool for improving match endurance and explosiveness in elite badminton players.

Rognmo et al. (2004) investigated the cardiovascular effects of high-intensity interval training using varying work-to-rest ratios and intensities in healthy adults. One of the key findings of their study was that a 4 × 4-minute interval protocol performed at 90–95% of maximum heart rate (HRmax) significantly enhanced VO_2max, a key indicator of cardiovascular fitness. This training format involves repeated high-intensity efforts interspersed with active recovery, and the researchers concluded that it provides superior aerobic benefits compared to moderate continuous training. In the context of badminton—where rallies can be intense, short, and unpredictable—this form of HIIT aligns well with the sport's physiological demands, especially during long matches that test endurance, speed, and repeated explosive effort. The study's implications support using interval formats that push the upper thresholds of cardiovascular effort to enhance stroke volume, oxygen uptake, and metabolic efficiency, thereby helping badminton athletes maintain high performance across extended competitive play.

Smith-Ryan, Melvin, and Wingfield (2014) explored the psychological effects of HIIT and found that repeated exposure to high-intensity workloads improves mental toughness, pain tolerance, and cognitive focus during physical stress. These traits are particularly critical in badminton, where players must endure long rallies, manage fatigue, and maintain concentration in dynamic and high-pressure match environments. Their findings suggest that HIIT challenges an athlete's mental limits, enabling them to build greater emotional control and performance consistency under duress.

Saw, Main, and Gastin (2016) emphasized the importance of using subjective monitoring tools, such as the Rating of Perceived Exertion (RPE) and daily wellness questionnaires, when implementing HIIT programs.

These tools provide valuable insights into how athletes feel and recover from high-intensity sessions, enabling coaches to personalize training and reduce the risk of overtraining. In sports like badminton, where recovery between training sessions and matches is essential for sustained performance, incorporating athlete feedback allows for better training load management, thereby optimizing both short-term performance and long-term athletic development.

Slimani et al. (2016) conducted a comprehensive systematic review examining the physical and psychological effects of high-intensity training modalities across a broad spectrum of athletic populations. Their findings revealed that consistent participation in HIIT not only leads to improvements in physical performance markers such as aerobic capacity, strength, and power but also fosters psychological benefits including heightened confidence, motivation, focus, and emotional resilience. These mental attributes are especially important in sports like badminton, where mental toughness and composure under pressure can influence match outcomes as much as physical skill. In competitive play, where athletes often face high-stress situations during extended rallies or closely contested points, the psychological conditioning achieved through HIIT can provide a performance edge. This underscores the holistic value of HIIT, making it a strategic tool for developing both the mental and physical readiness required in high-performance badminton.

Foster et al. (2015) emphasize the critical importance of structured periodization and athlete feedback systems to monitor and adjust training stress. Periodization refers to the systematic planning of training variables (volume, intensity, and frequency) across various phases (e.g., preparatory, competitive, taper) to optimize performance and recovery. In the context of HIIT, this means carefully sequencing high-intensity bouts throughout the macrocycle to avoid overtraining, ensure performance peaks during competition, and facilitate adaptation.

MacInnis and Gibala (2017) conducted a comprehensive meta-analysis examining the efficacy of low-volume high-intensity interval training (HIIT) in comparison to traditional continuous aerobic training. Their findings revealed that even brief HIIT sessions—often under 30 minutes in duration—can elicit equal or superior adaptations in endurance, muscular strength, and anaerobic power. These outcomes are particularly significant for athletes like badminton players, who typically juggle high technical and tactical training demands with limited time for physical conditioning. The study supports the notion that time-efficient HIIT protocols can optimize cardiovascular and neuromuscular development without compromising practice time devoted to skills and match simulation. Furthermore, the improved power output, oxygen utilization, and mitochondrial function associated with low-volume HIIT are well-suited to the intermittent and explosive nature of badminton rallies, offering a practical and effective training approach for improving on-court performance.

Weber et al. (2024) also noted that group-based HIIT sessions had slightly more favorable outcomes than individual programs, suggesting a possible social or motivational component that boosts adherence and emotional satisfaction. Furthermore, the review underlined that the positive psychological effects were not confined to physically elite participants but were consistently observed across general, clinical, and aging populations.

Campos et al. (2023) conducted a systematic review focusing on the effects of High-Intensity Interval Training (HIIT) on physical performance in female team sport athletes. Their review synthesized findings from 17 randomized and non-randomized controlled trials involving female athletes from various sports such as soccer, basketball, handball, and hockey. The primary objective was to determine how HIIT influences key performance indicators, including repeated sprint ability (RSA), aerobic capacity (VO_2 max), explosive power, and agility, which are fundamental to performance in intermittent high-intensity sports.

3 DESCRIPTIONS OF BROAD AREA

Aerobic capacity

The ability of the cardiovascular system to provide O2 to working muscles and the ability of those muscles to extract O2 for energy generation in the form of adenosine triphosphate (ATP).

Anaerobic Capacity

The maximal amount of ATP resynthesized through anaerobic metabolism during a specific mode of short period of maximal exercise.

Aerobic Heart Rate Zone

70% - 80% of max. heart rate (12- 25min)

Anaerobic Heart rate zone 80% - 90% of max. heart Rate. **Vo2 max**

Max. amount of O2 the body can consume during a maximal intensity workout.

Vital Capacity

The maximum amount of air forcefully exhaled from the lungs after fully inhaling

Agility

It is the ability to move one's body quickly, with coordination and balance.

Flexibility

The ability of muscles, tendons, and joints to stretch and return to their original position. It encompasses the range of motion and elasticity of these structures, which are crucial for optimal physical performance and injury prevention during exercise and everyday activities.

Balance

Balance refers to the ability to maintain a stable and controlled position or posture while performing various movements. It involves the coordination of multiple sensory systems, including the visual, vestibular (inner ear), and proprioceptive (body position) systems, to achieve and sustain equilibrium.

4 OBJECTIVES OF THE STUDY

PROBLEM STATEMENT

The present study is an attempt to find out the effect of the HIIT and IT programs on male badminton players.

Research Questions

This study aims to explore whether 'HIIT' offers greater benefits compared to 'IT' approach. Specifically, it investigates if HIIT can significantly improve both aerobic and anaerobic capacities, support the development of key physical attributes such as strength and endurance, and positively impact the physiological functions of the participating athletes. Additionally, the study will examine whether there is a noticeable difference in performance outcomes among the three groups involved: Group I (HIIT), Group II (IT), and Group III (control group with no specific training intervention).

RESEARCH OBJECTIVE

- To identify the result of the planned HIIT program on the performance of shuttlers.
- To find out whether the HIIT program is effective in developing physical and physiological performance.
- To find out the effectiveness of HIIT and IT programs in Badminton players, and then compare.
- To determine the changes that will occur in participants after training interventions.

LIMITATIONS

- A number of factors have been highlighted as limitations, including medicine, diet, daily routine, habits, and other elements that may have an impact on the study's findings.

- One of the study's limitations is the potential impact of the players' emotional states on their performance.

DELIMITATIONS

- 45 badminton players from Roing, District-Lower Dibang Valley, Arunachal Pradesh.
- Age ranged between 19-25 years, male.

- Variables to be studied are physiological and Physical.
- Training program (specifically selected for the study).

HYPOTHESIS

It is hypothesized that there will be a significant difference in the mean values of the players selected for physical and physiological variables after the training intervention of 8 weeks.

5 RESEARCH METHODOLOGY

SELECTION OF SUBJECT

A total of 45 badminton players are selected randomly for the study from Roing, district Lower Dibang Valley, Arunachal Pradesh. The selected subjects are aged between 19-25 years. Before participating in the study, the subjects are to submit informed consent. Further the participants will be distributed into three groups:

Group 1 (HIIT) : 15 subjects

Group 2 (I T) : 15 subjects

Group 3 (CONTROL): 15 subjects

SELECTION OF THE VARIABLE

Physical and physiological variables are selected for the current study.

PHYSICAL VARIABLES	PHYSIOLOGICAL VARIABLES
Jumping ability	Aerobic capacity
Agility	Anaerobic capacity
Flexibility	Vital capacity
Balance	Glucose level

TRAINING PROGRAM (HIIT)

DAYS	MORNING
MON	✓
WED	✓
FRI	✓

High-Intensity Interval Training (HIIT) provides various advantages for the cardiovascular system. These include improved cardiovascular fitness, increased aerobic capacity, lower resting heart rate and blood pressure, enhanced blood vessel function, increased levels of HDL cholesterol, reduced triglyceride levels, and improved insulin sensitivity. However, it's important to exercise caution and seek medical advice before beginning an HIIT program, especially if you have underlying health conditions or concerns.

TRAINING PROGRAM (IT)

DAYS	MORNING
TUE	✓
THU	✓
SAT	✓

Interval training is a structured method in sports training that involves alternating bouts of high or moderate-intensity work phases with periods of active or passive recovery. This approach is widely used to enhance both aerobic and anaerobic capacity, speed, and endurance by repeatedly challenging the body to recover quickly between efforts. It allows athletes to perform at higher intensities for longer durations than during continuous training, making it especially effective for sports that require repeated bursts of effort, such as football, basketball, and handball. Interval training can be precisely manipulated in terms of work-to-rest ratios, intensity, and duration to target specific performance goals.

ADMINISTRATION OF THE TEST

Once all participants are gathered in the training hall, a detailed explanation of the training program will be

provided. The players will be encouraged to cooperate, and all necessary instructions will be communicated clearly. Everyone will be informed that their responses will remain confidential and will be used solely for research purposes. The research scholar will personally oversee the entire training program to ensure consistency and accuracy throughout the study.

CRITERION MEASURES

COMPONENT	EQUIPMENT
Aerobic Capacity	Coopers' run and walk test
Anaerobic Capacity	200mtrs sprint test.
Vital capacity	Spiro meter
Glucose level	Glucometer
Balance	Flamingo balance test
Agility	shuttle run
Jumping ability	sergeant jump
Exercise Intensity	HR10 Polar
Flexibility	Sit and reach

PROCEDURE OF DATA COLLECTION

The data will be collected from the subject on selected physiological and physical variables. The data is taken before the experimental intervention (pre-test) and after 8 weeks of the training program (HIIT and IT) is completed (post-test). The performance recorded is retrieved from the results of the test conducted by the researcher.

1. Exercise Intensity – HR10 Polar Monitor

Objective: To monitor heart rate response to exercise and assess intensity levels.

Procedure: The HR10 chest strap will be used. Start the activity and record real-time heart rate data. Compare heart rate against target zones (50–85% of max HR), the data will be used to analyze training zones and recovery.

2. Aerobic Capacity – Cooper's 12-Minute Run/Walk Test

Objective: To assess the aerobic (cardiovascular) endurance of an individual.

Procedure: A standard 400m track is preferred. The individual will run or walk as far as possible in 12 minutes. The total distance covered will be measured. Pacing and consistent effort throughout will be encouraged.

Use results to estimate VO_2 max using the formula:

VO_2 max=(22.351×kilometres)−11.288\text{VO_2 max} = (22.351 \times \text{kilometres}) - 11.288VO_2 max=(22.351×kilometres)−11.288

3. Anaerobic Capacity – 200 Metres Sprint Test

Objective: To evaluate the anaerobic power and sprinting capacity of an individual.

Procedure: A 200m track will be used. The participants will warm up properly. The participant will be sprinting the full 200 meters at maximum effort. A stopwatch will be used to record time. Full recovery after the test will be ensured.

4. Vital Capacity – Using a Spirometer

Objective: To measure the maximum amount of air a person can exhale after maximum inhalation (vital lung capacity).

Procedure: A spirometer will be used to measure the vital capacity. The subject will be instructed to inhale deeply and exhale forcefully into the mouthpiece. Three readings will be taken, and the best will be recorded. It will be ensured that the subject is relaxed and seated.

5. Glucose Level – Using a Glucometer

Objective: To measure the blood glucose (sugar) level.

Procedure: A glucometer and sterile lancet will be used. The fingertip will be cleaned with an alcohol swab. Prick the fingertip to extract a drop of blood. Place blood on the test strip and insert it into the glucometer. The record of the glucose level will be recorded in (mg/dL or mmol/L).

6. Balance – Flamingo Balance Test

Objective: To assess whole-body balance.

Procedure: The participants will be standing on a beam or flat surface with one foot, the free leg bent at the knee. The stopwatch will be started once the person lifts their foot. The balance lost within 60 seconds will be recorded. More falls = lower balance ability.

7. Agility – Shuttle Run Test (4x10m or 5x10m)

Objective: To evaluate agility and speed during quick directional changes.

Procedure: Two lines will be set 10 meters apart. On command, the participants will be sprinting to the opposite line and returning (multiple times, depending on the version). The stopwatch starts on “Go” and stops at the end. The time taken to complete the shuttle will be recorded.

8. Jumping Ability – Sergeant Jump Test (Vertical Jump Test)

Objective: To assess explosive leg power.

Procedure: The standing reach height of the participants will be marked on a wall. The participant will jump vertically, marking the highest point reached. The difference between reach and jump height is the score. 2–3 trials will be taken; the best score is recorded.

9. Flexibility – Sit and Reach Test

Objective: To assess lower back and hamstring flexibility.

Procedure: The participant will be sitting on the floor with legs straight, feet flat against the box. Reach forward with both hands, palms down. Hold the stretch for 1–2 seconds. The distance reached beyond the toes (in cm or inches). Repeat 2–3 times; record the best attempt.

STATISTICAL TECHNIQUE USED

The following statistical techniques are to be used to evaluate the collected data.

i. Descriptive statistics are employed to compare the mean score of all groups.
ii. Analysis of covariance (ANCOVA) is employed to find out the significant difference between pre and post-means of all groups at the 0.05 level of significance.
iii. The LSD (least significant difference) post hoc test is used if the F-value is found to be significant.

6 EXPECTED OUTCOMES OF THE RESEARCH

The present study is anticipated to yield valuable insights into the differential effects of High-Intensity Interval Training (HIIT) and traditional Interval Training (IT) on the physical and physiological performance of male badminton players. Based on existing literature and the structured training interventions, the following outcomes are expected:

1. HIIT will demonstrate greater efficacy than IT in enhancing both aerobic and anaerobic capacity, as HIIT incorporates repeated bouts of high-intensity effort followed by rest, thereby stimulating both energy systems more efficiently.
2. Significant improvements are anticipated in physical attributes such as jumping ability, agility, flexibility, and balance among participants in the HIIT group compared to both IT and control groups, due to the dynamic and explosive nature of HIIT routines.
3. Physiological markers like vital capacity and glucose level regulation are expected to show more positive adaptation in the HIIT group. HIIT has been associated with better glucose metabolism and improved pulmonary function in related studies.
4. Participants in the IT group may show moderate improvements in performance variables, particularly

aerobic capacity and flexibility, but to a lesser extent than those in the HIIT group.

5. The control group is expected to exhibit minimal to no significant changes in any measured variable, reinforcing the influence of structured training interventions on athletic development.
6. A statistically significant difference is likely to be observed in post-intervention comparisons between Group I (HIIT), Group II (IT), and Group III (Control), particularly favoring HIIT for most variables.

These anticipated findings will contribute to evidence-based recommendations for conditioning programs specific to badminton and other sports requiring a balance of agility, power, and endurance.

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